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4.0 DATA

Two types of data were employed in developing this report. Initially, the mass of uranium shipped between sites is of interest. These data can be matched between shipper and receiver to quantify the potential for exposures to recycled uranium and to bound the level of uncertainty or error. Receiver/Shipper data are expressed in various units including grams of uranium (g U), kilograms of uranium (Kg U), and metric tons uranium (MTU)* and is presented by fiscal years for 1962 through 1999. In order to adequately assess the types and amounts of constituents in the uranium shipments and receipts, a second type of data is employed. This data type is comprised of analytical laboratory data representing samples of various materials taken at the time of shipment/receipt or taken directly from production processes. The following sections further describe the data collection, qualification, and utilization for each of these two types of data.

4.1 DATA COLLECTION AND SOURCES

4.1.1 FEMP

Receiver/Shipper Data

In order to develop data on shippers and receivers, reports prepared by the contractor for DOE were used:

1951 – 1967:	National Lead Company of Ohio SS Material Accountability Reports National Lead Company of Ohio Nuclear Materials Management Report
1968 – 1972:	Nuclear Materials Management and Safeguards System (NMMSS) Reports (M-742)
1973 – 1976:	NLO Nuclear Material Balance Reports
1977 – Present:	Nuclear Materials Management and Safeguards System (NMMSS) Reports (M-742)

* A metric ton uranium (MTU) is equal to 1,000 kilograms uranium (Kg U) or 1,000,000 grams uranium (g U).

Analytical Data

In order to adequately assess the types and quantities of recycle constituents in the recycled uranium received and shipped by the Fernald Site, a lengthy search for existing laboratory data with transuranic element data was performed. This effort consisted of the following elements:

- Search site records archive for original analytical data report forms with transuranic (Pu, Np) and fission product (Tc) data reported.
- Collect transuranic and Tc data maintained in current site inventory and analytical systems.
- Collect hardcopy results from mid-1980s efforts to track transuranics through FEMP processes.
- Request and collect data from other DOE sites pertaining to Fernald.

The data collected from these various sources were translated or transcribed to electronic form to facilitate combining the data into a large summary database. The source of the original data was maintained throughout the process to insure an ability to re-examine the original source for more information at a later time as part of the data analysis.

In developing the electronic data files, the files were named for the source, such as SKINEEL.XLS for data about Fernald depleted metal products provided by the Idaho National Engineering and Environmental Laboratory. Source data files generally have a commonality that is important to the interpretation of the results. In the case of SKINEEL.XLS, this file provides the only data available to the project representing depleted uranium metal made from UF_6 to UF_4 source uranium. It also represents enrichment facility tails. The result of statistical analysis of this data provides insight into the level of transuranics contained in the depleted UF_6 stream.

4.1.2 RMI

Receiver/Shipper Data

Reports similar to those used by the FEMP were used for the receiver and shipper data for RMI. Additional checks were completed to balance this information against the information available at the FEMP.

Analytical Data

Analytical data used for the RMI facility was based on information and analytical data gathered for the FEMP.

4.1.3 WVDP

Receiver/Shipper Data

There was no receiver data generated for this facility as it was a source of recycled uranium. Several reports were published that provided shipper data. The majority of the materials was shipped to the FEMP.

Analytical Data

Analytical data used for the WVDP facility was based on information and analytical data gathered for the FEMP.

4.1.4 WSSRAP

Receiver/Shipper Data

There was limited receiver and shipper data available from the WSSRAP facility. The information was primarily found from an overall report of their production history and is referenced in Appendix A.

Analytical Data

Analytical data used for the WWSRAP facility was based on information and analytical data gathered for the FEMP. In addition, the primary source of the materials at the WSSRAP was natural uranium.

4.2 DATA QUALIFICATION

4.2.1 FEMP

Receiver/Shipper Data

The data for this report has been garnered from reports required by DOE. We worked with Oak Ridge, RMI, Hanford, Savannah River, Paducah and Portsmouth to balance receipts. We are generally in balance with all sites. We are still working with Portsmouth, Paducah, and RMI to reconcile a few remaining data gaps. The data generated for this report was originally entered by the Material Control and Accountability Department and reformatted by the team. Careful attention was paid at each step of the process to balance back the MC&A data.

Analytical Data

Since much of the data required by the project had been developed as much as 20+ years prior to the project kickoff, strict adherence to a data validation protocol was not practical. Much of the data pre-dates current strategies for analytical data validation, however, that in itself does not invalidate the data. Radiochemical analytical capabilities have not changed dramatically in the past 20+ years, except for the addition of computer controls, counting aides, etc. The project staff determined that the need for data points for the project far outweighed any potential negative impacts that could arise from the use of data of uncertain quality control. Prior programs required reliable data from which to make decisions, so these prior data were presumed reliable. In support of efforts to disposition FEMP nuclear materials, prior FEMP analytical results have been compared with later resamplings of the same materials with good results, further justifying the decision by the project team.

As described in the prior section, a database of known analytical data was created, and then the process to evaluate the data was undertaken. An early step in the process was to translate the wide variety of data units of measure into a limited series of common units. In general, the data desired for each of the constituents was a mass-based unit rather than activity-based units, more typical of the laboratory data. Parts per billion on a uranium basis was chosen as the most useful form of the constituent data to permit the application of average results to large groups of uranium masses in order to calculate constituent mass content.

Once all of the data was expressed in mass units, the next concern was to identify and remove duplicate data points from the database. Since so many different data sources were utilized, a significant number of data points was found to be either complete duplicates or to be partial duplicates with additional data supplied by one or more of the duplicates. Duplicates were generally deleted from the master record (not from the individual sources) after inspection to confirm the record was a duplicate and not a second sample of the lot.

The final data check was to look at data reasonableness (a quality assurance practice). The database includes approximately 4,000 analytical results reporting Pu239, one of the principal constituents of interest. The range of results spans 8 to 9 orders of magnitude for this analyte, illustrating the diverse cross-section of the Fernald processes and material sources represented by the data. Several levels of data reasonableness checks were performed on the data.

The first check was performed as the data was being assimilated into the master database. Values for Pu239 falling outside expected results (both high and low) were further examined to verify conversions were applied correctly. This effort identified a number of systematic errors in data conversions (both as part of the project effort and in historical data) and is further discussed in Appendix C.

A second round of data checks was undertaken in a systematic manner to prepare the data for the initial phase of statistical analysis. The project team utilized knowledge gained from process knowledge sources, as well as utilizing chemistry principles to identify 11 sub-groupings of the data to reflect natural divisions between the various materials. Since the FEMP received uranium from various sources and also utilized chemical processes that could have resulted in the separation (potential for concentration) of constituents, these variables also were utilized in the identification of data sub-groups. Table 4-1 below identifies the sub-groupings identified by the project team.

The sub-groupings of data were then scanned by project personnel for reasonableness in relation to the expectations and the range of resultant values in the grouping. The creation of Sub-Group 4 resulted from the realization that the normal isotopic range of what otherwise would have been categorized as Sub-Group 7, was consistently significantly lower in Pu-239 than other components of Sub-Group 7. The project team chose to establish the separate sub-group to permit separate handling of the data analysis for these materials. Production records suggest that the bulk of the later production of normal metal at the FEMP was UF_6 source uranium rather than blended-down fresh reactor recycle uranium. This would account for a different analytical results regime for Pu-239 and other constituents of interest for this material and provide technical justification for the addition of the sub-group as well.

TABLE 4-1A

FEMP SUB-GROUPINGS OF DATA FOR STATISTICAL ANALYSIS

Sub-Grouping Number	Sub-Category Title/Description
1A	Miscellaneous Materials
1B	Miscellaneous Materials from Minor Off-Site Sources
2	UF_4 prepared from UF_6 Sources (GDP Tails)
3	UF_6 Source Metal & Scrap
4	Normal U Products, Residues, & Scrap
5	U Intermediates and Products from Enriched UF_6 Sources
6A	A508 UO_3 (PUREX Source – Unblended)
6B	UO_3 and Residues/Intermediates from A508 UO_3 (Low Cross-Over Potential)
6C	UO_3 and Residues/Intermediates from A508 UO_3 (High Cross-Over Potential)
6D	A500 Coded Enriched Residues
6E	Savannah River Source Uranyl Nitrate (PUREX)(Prior to Conversion to UO_3)
6F	Savannah River UO_3 (Mark 15) (Not Shipped to FEMP)
7A	Derbies prepared from A508 UO_3 (Potentially Blended)
7B	Ingots/Other Metal prepared from A508 UO_3 (Potentially Blended)
8	Enriched MgF_2
9	Incinerator Ash & Scrap Residues
10A	Tower Ash & Decontamination Residues
10B	UO_3 Produced from Tower Ash Receipts
11	Waste Residues Lower than Economic Discard Limit (EDL)

Note: Sub-Group #1, Miscellaneous Materials includes materials believed to be minor contributors in the overall effort to understand constituent flows between sites and/or reflects materials not well enough understood to categorize at this time.

4.2.2 RMI

Receiver/Shipper Data

The data used for RMI were developed from the results of the FEMP data. Table F.4-1B details the data source and rationale for using those results.

Analytical Data

The data used for RMI were developed from the results of the FEMP data. Table F.4-1B details the data source and rationale for using those results.

4.2.3 WVDP

Receiver/Shipper Data

The data used for WVDP were developed from the results of the FEMP data. Table F.4-1C details the data source and rationale for using those results.

Analytical Data

The data used for WVDP were developed from the results of the FEMP data. Table F.4-1C details the data source and rationale for using those results.

4.2.4 WSSRAP

Receiver/Shipper Data

The data used for WSSRAP were developed from the results of the FEMP data. Table F.4-1D details the data source and rationale for using those results. The primary source of materials for this facility were natural uranium.

Analytical Data

The data used for WSSRAP were developed from the results of the FEMP data. Table F.4-1D details the data source and rationale for using those results. The primary source of material was natural uranium.

4.3 DATA REPRESENTATIVENESS

4.3.1 FEMP

Receiver/Shipper Data

The data shipments and receipts were from reports required by DOE. It represents year end balances as reported to DOE each year.

Analytical Data

The representativeness of the project analytical data can be viewed from two perspectives: data coverage for material categories (sub-groups), and data coverage by chronological period. An attempt has been made to assure adequate data coverage for the major sub-groups of recycled uranium processing performed at the FEMP. Although several sub-groups of data have relatively limited datasets, the coverage is believed adequate.

Since analytical data uncovered in the FEMP records search is limited to later years of production, very little coverage of chronological periods was achieved with the Fernald dataset. This shortcoming is addressed by relying on the collective process knowledge of the DOE Complex. For example, the constituent decontamination capabilities of the Hanford REDOX process are believed to be similar but somewhat reduced from the capabilities of the later Hanford PUREX process. Since FEMP site data would only provide a basis for understanding the operation of the PUREX, the collective agreement of knowledgeable individuals coupled with available references was utilized in determining a time-adjusted basis for constituent concentrations from the REDOX process. A similar process was employed for other pieces and is represented in the major FEMP processing campaigns chart (Appendix D, Attachment 3, Figure 1). This figure provided a framework from which to knowledgeably evaluate chronological period data coverage and to determine the need for adjustments to existing data to account for changed operations.

4.3.2 RMI

Receiver/Shipper Data

The receiver and shipper data were taken from DOE reports.

Analytical Data

The representativeness of the project analytical data can be viewed from two perspectives: data coverage for material categories (sub-groups), and data coverage by chronological period. An attempt has been made to assure adequate data coverage for the major sub-groups of recycled uranium processing performed at the FEMP is appropriate for representing the RMI analytical data. Although several sub-groups of data have relatively limited datasets, the coverage is believed adequate.

4.3.3 WVDP

Receiver/Shipper Data

The receiver and shipper data were taken from reports issued by DOE on the history of the plutonium reprocessing plant.

Analytical Data

There was only one data point available that was used to represent the analytical data for the WVDP.

4.3.4 WSSRAP

Receiver/Shipper Data

The receiver and shipper data were taken from a historical report issued by DOE on the historical operations at the WSSRAP.

Analytical Data

The majority of the material processed at the WSSRAP was natural uranium and therefore had no constituent of concern. The analytical data for the remainder of the materials can be viewed from two perspectives: data coverage for material categories (sub-groups), and data coverage by chronological period. An attempt has been made to assure adequate data coverage for the major sub-groups of recycled uranium processing performed at the FEMP as it applies to the WSSRAP. Although several sub-groups of data have relatively limited datasets, the coverage is believed adequate.

4.4 DATA ANALYSIS

4.4.1 FEMP

The analysis of data for the project is composed of two distinct phases: Statistical Analysis, and Uncertainty Analysis. The two phases are further described below as applied to this project.

Statistical Analysis

Receiver/Shipper Data

No statistical analysis is required for the Receiver/Shipper data for the project. These data are the record of transactions of materials shipments between sites.

Analytical Data

As described above (Section 4.2.2), the division of the analytical results dataset into sub-groupings was performed to categorize the data by process source attributes. These groupings were intended to segregate the data regimes for use in determining the recycle constituent flows associated with the uranium flows (Receiver/Shipper data). By creating what was postulated to be process/chemistry-based groupings, the project team intended that the separate regimes bounded by the sub-group definitions would be statistically evaluated to identify a representative value for the regime. This representative value would in turn be utilized to calculate constituent content in the mass flows of uranium between the sites.

The statistical analysis was composed of the following steps:

- Review data Sub-Groups for duplicate records and other anomalies.
- Assess "less than" values to determine statistically valid approaches for representing these values.
- Assess the statistical distribution of constituent (Pu239 ppbU, Np237 ppbU, and Tc99 ppbU) data.
- Based on the distribution determined, identify an approach to represent each dataset (i.e. for normal distributions, the mean of the dataset could be adequate, however, for non-normal distributions other more advanced approaches are required).
- Perform additional relational checks on the data, such as evaluating the occurrence of correlations between various data values.

Table 4-2 presents data for the representative constituent value for each data sub-group. The values included in this table reflect the statistical analyses prepared to support the publishing of the final of the DOE Ohio Sites Recycled Uranium Project Report on May 15, 2000.

Analysis of the data sub-groups resulted in the determination that none of the constituent data sub-groups conform to pure a distribution. Although pure distributions (those that would conform well to normal or log-normal distributions) were desired and initially expected, the lack of conformance to a standard type of distribution is not uncommon and does not adversely affect application of the data. In all cases, the datasets were determined to be best represented by the use of a simple arithmetic average of the data values. The statistical evaluations performed on the data sub-groups have been provided by Attachment 1 to this appendix to illustrate the data sets and provide the values resulting from the analyses. Attachment 1 provides additional discussion on the presentation of the data and provides the specific outputs from the analysis of the data. Sub-group distribution plots (both quantile and histogram types) are provided in the attachment to illustrate the data set distributions, typically against a log-normal distribution assumption.

TABLE 4-2A

FEMP REPRESENTATIVE CONSTITUENT VALUES BY DATA SUB-GROUP

Sub-Group Number	Sub-Group (S/G) Title	Value for Pu-239 ppb U	Value for Np-237 ppb U	Value for Tc-99 ppb U
1A	Miscellaneous	16.035	1,328.11	2,399.22
1B	Miscellaneous – Minor Offsite	0.889	109.07	0.55
2	UF_6 Source UF_4 (GDP Tails)	0.502	54.90	201.61
3	UF_6 Source Metal & Scrap	0.007	2.54	9.12
4	Normal U Products, Res & Metal Scrap	0.091	67.09	26.55
5	Enriched UF_6 Source Products/Res.	1.259	81.39	2,109.61
6A	UO_3 PUREX Source (A508)(Unblended)	2.884	388.97	8,552.23
6B	A508 UO_3/UF_4 & Res. (Low Cross)	2.321	332.94	8,934.58
6C	A508 UO_3/UF_4 & Res. (High Cross)	23.969	1,045.29	2,789.56
6D	A500 Coded Enriched Residues	4.556	143.75	1,085.45
6E	SR UNH	16.527	--	--
6F	SR UO_3 – Not Shipped to FEMP	2.805	--	--
7A	A508 based Derbies	9.305	311.97	1,721.00
7B	A508 based Ingots & Metal	1.165	263.48	447.81
8	Enriched MgF_2	96.618	1,881.53	1,651.23
9	Incinerator Ash & Scrap Res. From GDPs	47.616	3,164.53	263.32
10A	Tower Ash & Decon Res.	412.177	10,503.53	2,618.36
10B	UO_3 from Tower Ash	20.772	498.17	2,405.28
11	Waste Residues <EDL	84.817	3,999.32	4,110.05

Uncertainty Analysis

Receiver/Shipper Data

Balancing activities were performed with Hanford, Savannah River, RMI, Portsmouth, and WVDP. Balances were achieved with these facilities.

Analytical Data

As discussed in Section 4.2.2, much of the analytical data available to the project existed independent of knowledge of the level of quality control incorporated in the values reported. These data were generated by a variety of laboratories to represent the samples received by them at the time. By qualitative analysis, the project team has adopted the position that only reliable data would have been reported and documented in records of any particular time period. Thus, the records search phase of the project would

generate data suitable for use by the project to reflect the materials in question. This assertion cannot be proven, but is reasonable, nonetheless.

It is further known that radiochemical analysis methods and base technology have not materially changed over the past 20+years (discounting the enhancements associated with computer automation of the laboratory processes). More recent data in the datasets typically have been reported with detection limits and the analytical database reflects data reported at less than the detection limits for the method, when available.

Because of the conditions inherent in utilizing these data, the most reasonable approach for an uncertainty analysis was determined to be a sensitivity analysis. The sensitivity analysis was based on typical experience in the variability of the results from the current laboratory processes utilized to produce constituent data. A confidence value for each process was determined and is applicable to the statistical confidence of each dataset.

4.4.2 RMI

Statistical Analysis

Receiver/Shipper Data

No statistical analysis is required for the receiver and shipper data for the project. These data are the record of transactions of materials shipments between sites.

Analytical Data

Analysis of the data sub-groups resulted in the determination that none of the constituent data sub-groups conform to a pure distribution. In all cases, the datasets were determined to be best represented by the use of a simple arithmetic average of the data values.

TABLE 4-2B
RMI REPRESENTATIVE CONSTITUENT VALUES BY DATA SUB-GROUP

Sub-Group Number	Sub-Group (S/G) Title	Value for Pu-239 ppb U	Value for Np-237 ppb U	Value for Tc-99 ppb U
3	UF_6 Source Metal & Scrap	0.007	2.54	9.12
4	Normal U Products, Res & Metal Scrap	0.091	67.09	26.55
6A	UO_3 PUREX Source (A508)(Unblended)	2.884	388.97	8,552.23
7A	A508 based Derbies	9.305	311.97	1,721.00

Uncertainty Analysis

Receiver/Shipper Data

Balancing activities were performed with other sites. Minor discrepancies were found, however they were well within the bounds for the project from an overall basis.

Analytical Data

Much of the analytical data available to the project existed independent of knowledge of the level of quality of control incorporated into the values reported. By qualitative analysis, the project team has adopted the position that only reliable data would have been reported and documented in the records used for this effort. Due to the conditions inherent with using the available data, the most reasonable approach for an uncertainty analysis was determined to be a sensitivity analysis.

4.4.3 WVDP

Statistical Analysis

Receiver/Shipper Data

No statistical analysis of receiver and shipper data is required.

Analytical Data

WVDP UNH shipments to the FEMP are represented by a single data point located in the FEMP analytical data that represents a shipment from the WVDP; therefore, no table is provided.

Uncertainty Analysis

Receiver/Shipper Data

There was only minor uncertainty in the receiver and shipper data, which was taken from issued reports. The uncertainty was based on the years (fiscal year versus calendar year) accounting. The amount shipped to the Oak Ridge facility was determined as the difference between what was received at the FEMP and the overall shipped data reported by the WVDP.

Analytical Data

The uncertainty of the analytical data is high for this facility in that the total shipments were based on a single data point. However, a review of the data point by the project team concluded that this value was fairly representative of material received at the FEMP.

4.4.4 WSSRAP

Statistical Analysis

Receiver/Shipper Data

There was no statistical analysis required for the receiver and shipper data. The report used to delineate the receipts and shipments for this facility was not broken out by facility and the convention was used that what could not be directly attributed to known facilities was included in the other sites category.

Analytical Data

The primary source of materials at the WSSRAP was natural uranium and would therefore not have any of the constituents of concern.

TABLE 4-2D
WSSRAP REPRESENTATIVE CONSTITUENT VALUES BY DATA SUB-GROUP

Sub-Group Number	Sub-Group (S/G) Title	Value for Pu-239 ppb U	Value for Np-237 ppb U	Value for Tc-99 ppb U
3	UF_6 Source Metal & Scrap	0.007	2.54	9.12
6A	UO_3 PUREX Source (A508)(Unblended)	2.884	388.97	8,552.23

Uncertainty Analysis

Receiver/Shipper Data

Due to the lack of information provided for the facilities receiving shipments from the WSSRAP, there is a high uncertainty in the distribution of the materials throughout the complex. However, the amount of these materials is extremely small compared with any other site included in this project and therefore has a minimal impact on the overall mass balance.

Analytical Data

Much of the analytical data available to the project existed independent of knowledge of the level of quality of control incorporated into the values reported. By qualitative analysis, the project team has adopted the position that only reliable data would have been reported and documented in the records used for this effort. Due to the conditions inherent with using the available data, the most reasonable approach for an uncertainty analysis was determined to be a sensitivity analysis.